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[DOCUMENT] Specification

[TITLE OF THE INVENTION] RC building Seismic Reinforcement Method Utilizing Steel Portal Frames without Braces

[WHAT IS CLAIMED]

[Claim 1] RC building seismic reinforcement method utilizing steel frame, stiffening existing RC-structure by fixing steel frame to the outside of the reinforced concrete structure with openings like windows, comprising;

said steel frame is a portal frame made of wide flange sections without braces, which is fixed to the outside of existing RC-column extending in the vertical direction and to the outside of existing RC-beam extending in the horizontal direction of said building, and

the wide flange section column of said portal frame fixed to existing RC-column is assigned to the bending rigidity roughly equivalent to that of existing RC-column,

whereby, not only reducing the stress additionally occurred at the connecting part between existing RC-column and wide flange section column by deforming the wide flange section column similarly to the existing RC-column under the horizontal load transmitted from existing RC-beam and/or wide flange section beam during an earthquake, but increasing the resultant strength in the horizontal direction of the combination of RC-column and wide flange section column by decreasing the deformation of RC-column after yielding so as to equalize the range of quasi-elastic deformation of said combination to that of elastic deformation of the wide flange section column.

[Claim 2] RC building seismic reinforcement method according to claim 1, wherein; said wide flange section column is a welded product of H-shape in cross section, web of which is arranged close to said RC-column.

[Claim 3] RC building seismic reinforcement method according to claim 1 or 2, wherein; said wide flange section column fixed to RC-column accompanies tie hoops welded on the outer surface of the web thereof, increasing bending rigidity thereof by

placing cement mortar or concrete into the space accommodating said tie hoops engaged with vertical bars.

[Claim 4] RC building seismic reinforcement method according to one of the claims 1-3, wherein; said wide flange section column is made of the steel of low yield point, reducing yield bending strength only without reduction of the bending rigidity thereof, whereby, reducing the response stress thereof during the earthquake through the plasticization hastened by yielding the combination of RC-column and wide flange section column at the bending strength of approximately 2 to 4 times as strong as the existing RC-column.

[Claim 5] RC building seismic reinforcement method according to one of the claims 1-4, wherein; said wide flange section column is stiffened by T-section, taking the form of T in plan view, extending all over the stories, the leg of which is welded on the outer surface of web of the column at its tip, whereby, three-dimensionally reinforcing the building by the alignment of T-sections with interior RC-beams or earthquake resisting walls not only extending perpendicularly to the external walls but being united to existing RC-columns to be reinforced by the wide flange section columns.

[Claim 6] RC building seismic reinforcement method according to claim 5, wherein; said T-section projects outside as wide as the verandah of each story.

[Claim 7] RC building seismic reinforcement method according to claim 6, wherein; said interior RC-beams or RC-beams over the existing earthquake resisting walls have additional beams made of high strength fluidized concrete or cement mortar on both sides thereof, whereby, not only obtaining the desirable bending moment based on the post-tension generated by unbonded prestressing steel bars buried in the additional beams but attaining the strength required in the horizontal direction of said beams.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[TECHNICAL FIELD]

The present invention relates to RC building seismic reinforcement method utilizing steel rigid frames without braces and, more particularly, to a method for stiffening a reinforced concrete building of low seismic resistance capacity by fixing steel portal frames to the external surfaces around openings such as windows of the

building.

[0002]

[PRIOR ART]

A reinforced concrete building of low seismic resistance capacity is often stiffened by enlarging the sectional area of columns thereof. For example, the existing RC-column 50 in Fig. 12(a) is covered with additional reinforced concrete 51 as shown in Fig. 12(b) or is wound by steel plates 52 as shown in (c). Such methods are applicable to a fully naked structure only like a bridge pier.

[0003]

A brace is another means for reinforcing structures. Such a reinforcement method is also applicable to schoolhouses, apartment houses and/or office buildings having columns which can not be processed on all sides, i.e., the brace is used to stiffen the RC portal frame comprising of columns and beams bridged over said columns.

[0004]

A portal frame is introduced into an existing RC-structure since it is impossible to directly bridge a brace over RC-column and RC-beam thereof. Fig.13(a) shows an example of steel portal frame 54 with braces 53 buried in the wall and (b) is an example of steel portal frame 55 fixed to the outside of columns and beams. These days, such kinds of steel portal frame with braces have been typical of the reinforcement by reason of not only a short period for reinforcement works but few increment of building weight. Especially, a method utilizing steel portal frames applied to the outside of existing building, being unnecessary to remove windows and walls around the windows thereof, has been increasingly used to remarkably shorten the period for reinforcement works.

[0005]

JP11-193639A1 discloses a method using steel portal frames applied to the external surfaces of columns and beams so that the reinforcement works may be carried out so quickly and easily. A brace makes such a portal frame for reinforcement more stable, i.e., the brace of the steel portal frame combined with RC-columns and RC-beams consequently reinforces RC-structure.

[0006]

Such a method can also reinforce the building while leaving inhabitants therein.

The frame made of wide flange sections introduces a sharp appearance into the old apartment house being often originally monotonous. Coloring frames sometimes changes the original appearance of house. Further, use of a tube-in-tube type brace (see e.g., JP11-193570A1) having an outer diameter much smaller than the members of frame provides the building with a lilting impression based on a smart figure of the brace.

[0007]

The recognition that the steel portal frame without braces never contributes for the reinforcement of RC-structure by reason of being more deformative than RC-column forces to introduce braces into steel portal frame. The thought that a brace is indispensable for the portal frame reinforcing RC-structure has already widely and deeply infiltrated in recent builders.

[0008]

The portal frame with braces need not equip the frame members with high rigidity, so that the sectional area of the members can be selected rather small. On the other hand, it is important to improve the characteristic of braces to be introduced into the frame, therefore, R&D for the improvement of brace has been still succeeded.

[0009]

The mentioned above teaches us that the frame is merely an auxiliary member as a toehold for fixing a brace to building. It has been believed that the steel portal frame being more deformative than RC-structure will not reinforce RC-structure, therefore, a brace is always necessary to stiffen the frame.

[0010]

[Cited Patent Reference No.1]

JP11-193639A1 (see pages 4-5 and Fig.1)

[0011]

[PROBLEMS TO BE SOLVED BY THE INVENTION]

The steel portal frame with braces, which the stress acting on the brace is transmitted to the columns and beams of its own frame, has the rigidity in the horizontal direction remarkably higher than, e.g., 50 to 100 times as high as that of steel rigid frame. The horizontal load acting on RC-structure 56 deforms mainly RC-column 57 as shown in Fig. 14(a) since the beams of building are generally locked by floor slabs thereof.

[0012]

As shown in Fig. 13(b) the steel portal frame 55 fixed to RC-structure 56, having higher rigidity than steel frame, results in being loaded with much larger horizontal forces than that of RC-structure. Fig. 15 teaches that the part except the cross of column and beam, e.g., a spot fixing a gusset-plate 59a on the steel beam 58, gathers horizontal forces transmitted to RC-beam 60. In this case, the distribution of stress transmitted from steel portal frame 55 to RC-beam 60 is shown by some arrows B departing from gusset-plate 59a, resulting in acting an extremely heavy load on stud dowels, etc., mentioned below.

[0013]

The steel portal frame 55 is united to RC-column 57 and RC-beam 60 with cement mortar or concrete placed into the space between them accommodating chemical anchors and/or stud dowels. The concrete formed in the space mentioned above results in being overloaded on the ground of the large difference of the allowable strength in the horizontal direction based on the rigidity in the horizontal direction of steel column 61 of portal frame 55 reinforced by a brace 53 from that of the RC-column 57 of RC-structure 56. In other words, the effect of reinforcement due to the steel portal frames is gradually lowered with the growth of damages of the concrete in connecting space being caused by the overload against the chemical anchors, etc.

[0014]

The braces fixed close to windows for the purpose of reinforcing the apartment house spoil the view from windows even if the braces are industrial refined products. The circumstance that even inhabitant wants to reinforce the apartment house does not always allow windows with braces to belong to his own living space often delays the seismic reinforcement of the apartment house as far as the interest between the inhabitants being forced to have windows with braces and other inhabitants not being forced is left.

[0015]

The introduction of brace into the steel portal frame requires the use of a gusset-plate 59, besides, requires a plenty of steel for the reinforcement of steel beam 58 to which the gusset-plate 59a fixed compared with the quantity spent for the reinforcement of the crossing of column and beam holding the gusset-plate 59b. The

span of the old building requiring the seismic reinforcement is generally so short that small steel portal frames for the building are often used. This teaches us that the rate of occupation of the secondary steel, i.e., gusset-plates, stiffening plates, etc., against the steel for columns and beams of portal frames will uneconomically rise.

[0016]

The object of the invention is to propose RC building seismic reinforcement method utilizing steel portal frames without braces in order to solve the problems mentioned before; the first is to obtain a trim appearance having windows without braces though the steel portal frames are applied to the outside of existing building, the second is to maintain the combination of steel portal frame and RC-structure as long as possible under the horizontal load repeated during a big earthquake, whereby, increasing the strength in the horizontal direction based on the reinforcement effect due to the steel portal frame before the building is destroyed so that the collapse of building in early stage may be avoided even at a big earthquake and the third is to save the steel for secondary use so that both simplification and inexpensiveness of the reinforcement are successfully achieved.

[0017]

[DISCLOSURE OF THE INVENTION]

The present invention is applied to RC building seismic reinforcement method utilizing steel frame, stiffening existing RC-structure by fixing steel frame to the outside of the reinforced concrete structure with openings like windows, comprising; referring to Fig. 1, the steel frame is a portal frame 3 made of wide flange sections without braces, which is fixed to the outside of existing RC-column 5 extending in the vertical direction and to the outside of existing RC-beam 8 extending in the horizontal direction, and the wide flange section column 4 of the portal frame fixed to existing RC-column 5 is assigned to the bending rigidity roughly equivalent to that of existing RC-column 5, being much less than that of steel portal frame with braces, whereby, not only reducing the stress additionally occurred at the connecting part 9 (see Fig. 2) between existing RC-column and wide flange section column by deforming the column 4 similarly to the existing RC-column 5 under the horizontal load transmitted from existing RC-beam 8 and/or wide flange section beam 6 during an earthquake, but increasing the resultant strength in the horizontal direction of the combination 10 of RC-column and wide flange section column by decreasing the deformation of RC-

column 5 after yielding so as to equalize the range of quasi-elastic deformation of said combination to that of elastic deformation of the column 4.

[0018]

As shown in Fig. 2(a), the wide flange section column 4 is preferably a welded product of H-shape in cross section, web 4w of which is arranged close to RC-column. Referring to (b), the column 4 fixed to RC-column 5 accompanies tie hoops 22 welded on the outer surface of the web 4w of the column, increasing bending rigidity thereof by placing cement mortar or concrete 24 into the space accommodating said tie hoops engaged with vertical bars 23.

[0019]

The wide flange section column 4 is made of the steel of low yield point, reducing yield bending strength only without reduction of the bending rigidity thereof, whereby, reducing the response stress thereof at a big earthquake through the plasticization hastened by yielding the combination of RC-column and wide flange section column at the bending strength of approximately 3 to 4 times as strong as the existing RC-column 5.

[0020]

Referring to Fig. 9, the wide flange section column 4 is stiffened by T-section 25, taking the form of T in plan view, extending all over the stories, the leg 25a of which is welded on the outer surface of web 4w of the column at its tip, whereby, three-dimensionally reinforcing the building by the alignment of T-sections with interior RC-beams 26A or earthquake resisting walls 26B not only extending perpendicularly to the external walls but being united to existing RC-columns 5 to be reinforced by the wide flange section columns 4.

[0021]

T-section 25A projects outside as wide as the verandah 27 of each story.

[0022]

As shown in Fig. 11(c) the interior RC-beams 26A or RC-beams over the existing earthquake resisting walls have additional beams made of high strength fluidized concrete 30 or cement mortar at both sides thereof, whereby, not only obtaining the desirable bending moment based on the post-tension generated by unbonded prestressing steel bars 31 buried in the additional beams, but attaining the strength required in the horizontal direction of said beams.

[0023]

[PREFERABLE EMBODIMENT]

RC building seismic reinforcement method utilizing steel portal frames without braces according to the present invention is disclosed below in detail referring to some examples. The invention relates to a method for stiffening an existing RC-structure by fixing the steel frame to the outside of a reinforced concrete structure with openings like windows. According to such reinforcement works a building may be reinforced while leaving inhabitants therein. What is notable in the invention is that the wide flange section column of the steel frame is assigned to the bending rigidity roughly equivalent to that of RC-column of reinforced concrete structure.

[0024]

The steel column is equipped with the bending rigidity of -70% to +200% as high as that of RC-column, accordingly, it never composes of a steel portal frames with braces having the huge bending rigidity of 50 to 100 times as high as that of RC-column. This means that the bending rigidity of wide flange section column fixed to existing RC-column is of the same order as that of RC-column, being much less than that of steel portal frame with braces.

[0025]

Fig. 1 shows an outside view of a part of one story with windows 2 in RC-structure 1 to which a portal frame 3 made of wide flange sections without braces mentioned above is fixed. The steel column 4 of portal frame 3 is combined with existing RC-column 5 extending in the vertical direction along the external wall of building and the steel beam 6 thereof is combined with an existing RC-beam 8 extending from RC-column 5 to the right and/or left sides thereof, supporting the load including the vertical load caused by the weight of external walls 7, etc.

[0026]

Although the steel portal frame 3 composed of wide flange section column 4 and wide flange section beam 6 has no braces, it is never assigned to the high rigidity corresponding to that of the steel portal frame reinforced by braces. The bending rigidity assigned to column 4 fixed to existing RC-column 5 is selected to be roughly equalized to that of the existing RC-column. It is noticeable that the steel column deformative approximately equivalent to the deformation of RC-column (being much more deformative than the frame with braces) is applied to the reinforcement of RC-

structure.

[0027]

In brief, the wide flange section column 4 results in deforming similarly to the existing RC-column 5 under the horizontal load transmitted from existing RC-beam 8 and/or wide flange section beam 6 at a big earthquake. The stress additionally occurred at the connecting part 9 shown in Fig. 2(a) between existing RC-column and wide flange section column comes to remarkably small in response to the decrease of difference of the bending deformation of existing RC-column 5 from that of column 4.

[0028]

In addition, since the deformation of RC-column 5 is restrained after yielding at the displacement in the horizontal direction shown by δ_{RC} in Fig. 3(a), the combination 10 of RC-column and wide flange section column 4 results in the possession of a broad range S of quasi-elastic deformation indicated by the line slightly bent, being regarded as approximately straight, up to the deformation corresponding to the elastic deformation δ_H in the horizontal direction of wide flange section column, furthermore, in great increase of strength in the horizontal direction thereof as described below.

[0029]

Since the yield bending stress of steel column 4 is much bigger than that of RC-column 5 in the case that bending rigidity of the steel column is of the same order as that of RC-column, the seismic resistance capacity of the combination of steel portal frame and RC-structure results in the increase of at least 3 to 4 times as large as RC-structure. The reinforcement according to the present invention not only generates much higher seismic resistance capacity than the existing reinforcement achieving the strength in the horizontal direction at most twice as strong as the existing RC-column, but keeps original openings without braces. The figure of steel portal frame made of wide flange sections, being more narrow than the width of columns and beams of existing reinforced concrete, simply blends well with the appearance of existing building, whereby, the reinforcement mentioned above comes to greatly practicable.

[0030]

Referring to Fig. 2, the portal frame 3 made of wide flange sections is combined with RC-columns 5 and RC-beams 8 by the use of chemical anchors 11, stud dowels

12, spiral hoops 13 and high strength non-shrink mortar 14. The existing building under the horizontal load mainly deforms the columns on the ground that the beams are always locked by floor slabs as described in Fig. 14(a).

[0031]

The bending rigidity of wide flange section column 4 being roughly equivalent to that of RC-column 5 under the condition that wide flange section beam 6 is united to RC-beam 8 makes column 4 deform similar to RC-column 5 as shown in Fig. 14(b) so that the difference of deformation of the former from that of the latter may be very little, consequently, reducing the stress transmitted through chemical anchors and/or stud dowels in the connecting part 9 (see Fig. 2) to a minimum.

[0032]

The big additional stress in the connecting part will not occur even under the horizontal load based on an earthquake, accordingly, the horizontal loads are smoothly transmitted from steel portal frames to RC-frames and vice versa. Such a steel rigid frame provides stud dowel, etc. with the uniform load due to the shearing force transmitted through all over the beams, being different from the frame with braces described in Prior Art.

[0033]

Steel portal frame 3 deforms similarly to RC-frame 1 as shown in Fig. 14(b) though the former is originally more deformative than the latter, whereby, simplifying the composition of connecting part as well as facilitating the rationalization of all over the reinforcement works from design to construction. The inventor's studies have taught that the deformation of existing RC-column comes to much the same as that of the wide flange section column provided that the bending rigidity of column 4 fixed to existing RC-column 5 is assigned to -70% to +200%, preferably -60% to +150%, as high as that of existing RC-column.

[0034]

Although today's builders believe that braces are indispensable for the reinforcement of RC-structure by reason that deformative steel frames will not stiffen a reinforced concrete building, the present invention dares to remove braces from steel portal frame. A tube-in-tube type brace is still an eyesore even if it has come to smart in appearance. Needless to say, the steel portal frame without braces according to the invention comes to acceptable for practicing the seismic reinforcement,

consequently, promoting the seismic reinforcement works against the buildings being not still reinforced.

[0035]

The steel portal frame without braces requires no gasset-plates for braces. Since braces being smart in appearance is often connected to frames by pin joints, the gasset-plates as joints are inevitably required thick, besides, the web of wide flange section column must be reinforced by stiffening plates, etc., for the sake of fixing gasset-plates thereto. Adopting no braces favorably results in requiring no reinforcements such as stiffening plates.

[0036]

Furthermore, a plenty of small steel portal frames for seismic reinforcement are spent for old building, especially, for out-of-date apartment houses 15 of short span shown in plan view of Fig. 4. Applying portal frame with braces to the building to be reinforced forces a high percentage of the occupation, being not negligible, of auxiliary reinforcements mentioned above against wide flange section as main reinforcements.

[0037]

Though the portal frame with braces can not hide the existence of secondary reinforcements applied to all over the frame, the portal frame without braces itself comes to inconspicuous due to few auxiliary reinforcements, approximately equal to zero, and it may look as if the building were not reinforced.

[0038]

The present invention makes the combination of RC-structure and steel portal frame behave in one united body without acting unfavorable force on the connecting part of the combination, therefore, the range of elastic deformation comes to large by decreasing the deformation of existing RC-column, and besides, the strength in the horizontal direction of the reinforced building greatly increases under the contribution of steel of big original strength. Such a steel portal frame needs braces no longer. The reinforcement of RC-structure without braces have not been achieved until the knowledge mentioned above is found out.

[0039]

The support which the wide flange section column having bending rigidity equal to that of existing RC-column is practicable is disclosed below with the explanation of

increasing the strength of the combination according to an example of calculation based on the model 16 of Fig. 5. Provided the cross section of RC-column 5 is 60 centimeters square, the geometrical moment of inertia thereof is given as follows:

[NUMERAL 1]

$$I = 60 \times 60^3 / 12 = 1{,}080{,}000 \text{ cm}^4.$$

[0040]

It is well-known on the design for earthquake-proof that 70% of original geometrical moment I of inertia of reinforced concrete is available even at the allowable strength (at the limit of elasticity) in spite of occurrence of little cracks thereon, accordingly, I_{RC} is obtained below:

[NUMERAL 2]

$$I_{RC} = 1{,}080{,}000 \text{ cm}^4 \times 0.7 = 756{,}000 \text{ cm}^4 .$$

[0041]

The yield bending strength (yield moment) of RC-column based on the geometrical moment of inertia is given below: Assuming that the total sectional area a_t of reinforcing bars is 17.02 cm^2 and allowable unit stress f_t thereof is 2.4 tons/cm^2, the distance between centers of tension and compression resultants j and the yield bending strength ${}_{RC}M_y$ are obtained as follows:

[NUMERAL 3]

$$j = 7d / 8 = 7 / 8 \quad (60 - 5.0) = 48.1 \text{ cm},$$

$$\text{therefore, } {}_{RC}M_y = a_t \cdot f_t \cdot j$$

$$= 17.02 \times 2.4 \times 48.1 = 19.65 \text{ t}\cdot\text{m}.$$

[0042]

Next, provided the wide flange section column 4 is 40 centimeters wide and 40 centimeters deep, thickness t_f of its flange = 2.5 centimeters and thickness t_w of its web = 1.6 centimeters, the geometrical moment I_S thereof is as follows:

[NUMERAL 4]

$$I_S = 20^2 \times 2.5 \times 40 \times 2 + 1.6 \times 40^3 / 12$$

$$= 88{,}533 \text{ cm}^4.$$

Since the ratio of Young's modulus of steel to concrete is approximately 10, the geometrical moment ${}_{eq}I_S$ of inertia equivalent to reinforced concrete column is written as follows:

[NUMERAL 5]

$_{eq}I_S = 88{,}533 \times 10 = 885{,}330\ cm^4$.

This is approximately equal to $I_{RC} = 756{,}000\ cm^4$ calculated above.

[0043]

Section modulus Z_S, yield bending strength $_sM_y$ and $_sM_y/_{RC}M_y$ of wide flange section column 4 are respectively as follows:

[NUMERAL 6]

$$Z_S = 88{,}533 / 20 = 4{,}427\ cm^3,$$

$$_sM_y = 4{,}427 \times 2.4 = 106.2\ t \cdot m$$

and $\quad _sM_y / _{RC}M_y = 106.2 / 19.65 = 5.4.$

The strength in the horizontal direction of the combination may theoretically increase by 5.4 shown above against 1.0 of RC-column to 6.4 times in the case that stud dowels and chemical anchors are enough for transmitting the strength of wide flange section column.

[0044]

Since Young's modulus of steel is about 10 times as large as that of concrete, the example of calculation teaches that a steel column of the bending rigidity similar to the reinforced concrete is easily obtainable. Although the nature of reinforced concrete is different from that of steel, their behavior is much the same within the range of elasticity. Since the yield bending strength of wide flange section column is higher than that of RC-column under the condition that the bending rigidity is the same among them, both the combination of RC-column and wide flange section column basically results in being elastic.

[0045]

As shown in Fig. 3(a) the strength in the horizontal direction of wide flange section column 4 made of ordinary steel is 5.6 times, at least keeping elastic, as strong as that of RC-column 5 being regarded as 1. The steel is loaded up to deformation δ_H in the horizontal direction corresponding to the limit of elasticity, whereby, the growth of damage of reinforced concrete remains within the deformation in the horizontal direction. If the yield bending strength of wide flange section column is low, the load on the reinforced concrete column increases accompanying with damage based on large deformation. According to the present invention the steel portal frame contributes to decrease the damage of reinforced concrete column also after yielding.

[0046]

Oppositely, the elastic behavior of the wide flange section delays the advance in collapse of reinforced concrete. Though a existing reinforced concrete structure absorbs seismic energy in compensation for being damaged, the reinforcement according to the present invention not only remarkably decreases the damage of reinforced concrete but lightens the repair works thereafter.

[0047]

As described above, the bending rigidity of wide flange section column fixed to existing RC-column is assigned to -70% to +200% as high as that of existing RC-column, i.e., 0.3 to 2.0 times. Above all, the bending rigidity of wide flange section column had better be bigger than that of existing RC-column. In consideration of spending steel 150% (= 1.5 times) is enough to restrain the occurrence of cracks on reinforced concrete also after RC-column 5 is beyond its elastic limit.

[0048]

On the other hand, approaching the absolute value of % to 100 on the negative side means not to reinforce the building, therefore, the value should be selected within at least -70%. Because even the steel having bending rigidity of only 30% of that of existing RC-column is expected enough for reinforcing existing slightly superannuated RC-structure. Any steel having much higher bending strength than the reinforced concrete greatly contributes to reinforce RC-columns, accordingly, transmitting the load to the base of building due to the decrease of damage of reinforced concrete as well as restraining the unstabilization of building in early stage.

[0049]

Use of the steel of low yield point (σ_y = 1.5t/cm^2) for the column 4 reduces the yield bending strength thereof only to about 1/2 as shown in Fig. 3(b) without reduction of the bending rigidity thereof. According to the example calculated above the yield moment of wide flange section column may be reduced from 5.4 times to 2.7 times as large as RC-column 5.

[0050]

Thus, wide flange section column can yield at the yield bending strength of 2 to 4 times as strong as existing RC-column, not only promoting the plasticization of wide flange section column at a big earthquake but reducing the response stress against

the earthquake. In other words, the absorption of seismic energy due to large plastic deformation against the excessive force greatly restrains an instantaneous collapse without quick reduction of strength of wide flange section column.

[0051]

Because the excessively high yield bending strength of wide flange section column occurs some problems in the toughness-type reinforcement for high-rise buildings in spite of almost no problems in the strength-type reinforcement applied to middle- and/or low-rise buildings. It is significant to reduce the yield bending strength for removing the problems described before.

[0052]

Fig. 3 shows diagrams of load vs. displacement in the horizontal direction under the condition that the bending rigidity of wide flange section column is the same as that of RC-column. The column 4 made of ordinary steel elastically behaves in broad range as shown in (a) needs to largely deform before the plasticization thereof based on a big earthquake.

[0053]

The other hand, (b) teaches us that wide flange section column begins to yield at the horizontal strength of about 3 times as strong as that of existing RC-column so that the wide flange section column may be plasticized in relatively early stage during a big earthquake. It is well-known that moderate plasticization of wide flange section column remarkably reduces the response against the earthquake. Accordingly, small response stress facilitates the design for not only the base of building but the whole parts of structure thereof to support the economical design.

[0054]

Selecting the bending strength of wide flange section column equivalent to that of reinforced concrete column is the basis of the present invention as explained above, then, giving rational composition of the connecting part. Fig. 6 is a diagram of load vs. displacement in the horizontal direction of RC-column 5 accompanying with the column 4 having different bending rigidity from that of RC-column, being drawn correspondingly to Fig. 3. In this case a combination of RC-column and wide flange section column will be not formed, accordingly, RC-column and wide flange section column deform independently. Therefore, the double-dotted chain line of N made by piling load vs. displacement of RC-column with that of wide flange section column,

being drawn similarly to the broken lines in Fig. 3, is not obtainable in practice.

[0055]

The thought of the present invention is expanded below: Fig. 7 shows the examples which the column 4 is fixed to the chemical anchors 11 driven into the RC-column 5. (a) is an embodiment of wide flange section column covering whole of the projecting part of RC-column 5, and (b) is another of column 4 facing a flat external surface only of RC-column. Thus, the wide flange section column is arranged so close to reinforced concrete that the narrow space 9A only between existing RC-column and wide flange section requires high strength non-shrink mortar.

[0056]

Arranging the column 4 close to RC-column 5 requires no stud dowels. The steel rigid frame structure can decrease the consumption of secondary materials in compensation for the increment of main materials in the case that the bending rigidity in the lateral (horizontal) direction of wide flange section column equivalent to that of reinforced concrete column can be obtained in spite of the reinforcement due to the wide flange section column slightly projecting from the external surface of reinforced concrete. The simplification of steel portal frame contributes to not only the decrease of construction works but the great reduction of total cost for reinforcement.

[0057]

Incidentally, the position for joining columns 4 vertically disposed in series to each other in the direction along the axis of column is assigned to the point where the bending moment M_5 of RC-column 5 in Fig. 8 is equal to 0 (being called a point of contraflexure). Because the middle point between upper beam 6u and lower beam 6d gives the bending rigidity of $M_4 = 0$ to column 4 as well as to RC-column 5. The steel plate 17 welded on the lower end of column 4 is joined to the steel plate 17 welded on the upper end of another column 4 by high tension bolts 18.

[0058]

Referring to Fig. 7, a hole 19 having an annular clearance 19a shown in (c) for allowing an inaccurate position of chemical anchor 11 against the wide flange section column 4 is formed in the web 4w of column so as to fix the column 4 to chemical anchors driven into the RC-column 5. Welding the washer 21 used for a nut 20, locking the column 4 to the RC-column, on the web 4w prevents the column 4 from moving.

[0059]

Both the wide flange rolled section with web 4W drawn by double-dotted chain lines in Fig. 2(a) and the welded product consisting of three long steel plates are available for any portal frame 3 explained before. The latter with the web 4w optionally designed concerning the position and/or size thereof may advantageously provide us with the products out of standardization of rolled section.

[0060]

Though the standardized products of rolled section with wide flange are used in general on the ground of mass-products, welded products of H-shape in cross section are greatly available if the web can be designed so as to obtain columns of bending rigidity equivalent to that of RC-column 5. The web 4w close to RC-column as shown in Fig. 2(a) makes a narrow space 9A between a wide flange section column and RC-column, whereby, decreasing the consumption of expensive high strength non-shrink mortar 14.

[0061]

A short distance between wide flange section column 4 and RC-column 5 is preferable for increasing not only strength but the bending rigidity of the connecting part as well as for aligning the web of wide flange section column with the web 6w of wide flange section beam 6, therefore, transmitting the horizontal force to other wide flange section without unfavorable shearing force and/or moment. In the case that the bending rigidity of wide flange section column is insufficient it can be increased not only by welding tie hoops 22 engaged with vertical bars 23 on the outer surface of web 4w of the wide flange section column as shown in Fig. 2(b) but by placing cement mortar or concrete 24 over them.

[0062]

The reinforcement mentioned above is applied to the building being loaded by the horizontal force in the direction of x-axis shown in Fig. 4(a). However, the old buildings to be reinforced often have small rooms divided by the wall extending in the direction of y-axis. It is impossible to remove earthquake resisting walls for the purpose of enlarging the rooms as far as interior RC-beams or the walls are designed so as to resist the horizontal force in the lateral direction, i.e., in the direction of y-axis.

[0063]

Increasing the number of earthquake resisting walls and/or the thickness of existing walls to reinforce the lateral direction of building makes the living space small. According to the present invention T-sections 25, taking the form of T in plan view, are arranged so as to extend all over the stories along the outer surface of the web 4w of the wide flange section column 4 as shown in Fig. 9. The leg 25a of T-section is welded on the wide flange section column 4 so that T-section is aligned with interior RC-beam 26A and/or earthquake resisting wall 26B extending perpendicularly to the external wall and being united to existing RC-column 5.

[0064]

Such T-section 25 provides the building with seismic reinforced columns forming H in the lateral direction (in the direction of y-axis in Fig. 4(a)) because T-section 25 is united to the web 4w of wide flange section column 4. Both wide flange section column 4 itself being originally seismic reinforced column in the directions of right and/or left sides (in the direction of x-axis) and T-section 25 extending from the first story to the top story unitedly achieve three-dimensional reinforcement, i.e., in the directions of x, y and z-axes of building. T-section 25 is fixed not only to the front surface but to rear surface of building as shown in Fig. 4(b) if necessary.

[0065]

The verandah spreading in series on each story provides the apartment house with space for reinforcing in the lateral direction thereof, then, utilizing the whole width of verandahs at the boundaries of neighboring houses. As shown in Fig. 4(b) the leg of T-section 25A is projected up to the handrail 27a (see also Fig. 9) on the line extended from the earthquake resisting wall, etc., by equalizing the length of leg 25a of T-section 25A to the width of verandah 27.

[0066]

In such a case both interior RC-beam 26A and earthquake resisting wall 26B should be reinforced as well as RC-column 5 combined with wide flange section column 4 on its external surface. Fig. 10 shows an example of living space 28 on one story, to not only the front side (see the left-hand side in the drawing) but rear side (see the right-hand side in the drawing) of which T-sections 25 are fixed. In this case the interior RC-beams 26A supporting floor slab 29 may be reinforced as shown in Fig. 11(c).

[0067]

Fig. 11(a) and (b) show the sectional views taking along line A-A and line B-B in (c) thereof, respectively. Not only placing high strength fluidized concrete 30 or mortar on both sides of interior RC-beams 26A as shown in (c) but generating post-tension in interior RC-beams by unbonded prestressing steel bars 31 buried in additional beams after curing the cement provide the interior RC-beams 26A with desirable bending moment at their ends, resulting in attaining the strength required in the horizontal direction of the beams. Such reinforcement enables to remove a part of existing earthquake resisting walls for the purpose of enlarging the living space.

[0068]

[EFFECT OF THE INVENTION]

According to the present invention which the wide flange section column fixed to existing RC-column is assigned to the bending rigidity roughly equivalent to that of existing RC-column one column results in deforming similarly to another, whereby, reducing the additional stress occurred by the difference of the deformation of RC-column from that of the wide flange section column in the connecting space faced thereto, and besides, remarkably decreasing the force transmitted through chemical anchors, etc.

[0069]

The instantaneous collapse of buildings during a big earthquake can be favorably avoided since the increase of strength in the horizontal direction based on the reinforcement due to steel portal frame before the collapse of building keeps the combination of steel portal frame and RC-structure as long as possible. In addition, the growth of damage of RC-column which should have yielded is restrained before the yield of wide flange section since the range of deformation due to elastic behavior of wide flange section column is wider than that of RC-column. Thus, not only the damage of RC-structure is decreased but the repair works thereafter is lighten due to delaying the absorption of seismic energy while collapsing reinforced concrete structure.

[0070]

Non-use of braces keeps the original view from windows and use of portal frame made of wide flange sections being narrower than the width of existing columns and beams hardly changes the appearance of building. All of inhabitants in an apartment house and of tenants in an office building may easily agree with the seismic

reinforcement works out of self-interest, therefore, accelerating the reinforcement works.

[0071]

In the case of connecting a brace to gasset-plate via a pin joint the gasset-plate is required rather thick. On the other hand, the steel portal frame without braces according to the invention need not such a gasset-plate itself, resulting in no reinforcement for the web of wide flange section beam. The removal of the steel materials secondarily used at a high rate for reinforcing old buildings being short in span promotes inexpensive reinforcement works.

[0072]

Arranging the web of wide flange section column close to RC-column facilitates to approximately equalize the bending rigidity thereof to that of RC-column. A narrow connecting part enables the alignment of the web of wide flange section column with the web of wide flange section beam having a cross section smaller than the wide flange section column, resulting in the transmission of horizontal force in high efficiency on the portal frame made of wide flange sections.

[0073]

The narrower the connecting part is, the shorter the distance for transmitting force is so as not to act the excessive force on the connecting part, resulting in saving very expensive high strength non-shrink mortar and the secondary materials, e.g., anchors, etc. Accordingly, not only the simplification of the connecting part but decrease the costs for construction are attainable through the reduction of the reinforcement materials and the rationalization of the reinforcement works.

[0074]

Both welding tie hoops engaged with main reinforcements on the outer surface of web of the wide flange section column and placing cement mortar or concrete over them increase the bending rigidity of the wide flange section column so that it may become approximately equivalent to that of RC-column even if the wide flange section column results in having low bending rigidity by reason of arranging the web thereof close to RC-column.

[0075]

Assigning wide flange section column to the steel of low yield point reduces the yield bending strength only without reduction of the bending rigidity, whereby, yielding

the wide flange section column at the bending strength of approximately 2 to 4 times as strong as the existing RC-column, consequently, the response stress is reduced by the plasticization of columns during a big earthquake.

[0076]

Both welding the end of leg of T-section on the outer surface of the web of the columns wide flange section and extending T-section all over the stories unitedly achieve the complete reinforcement of three axes of x, y and z, i.e., reinforcement in the horizontal direction of the external walls of the building, in the lateral direction perpendicular to the external walls and in the vertical direction of the external walls.

[0077]

Projecting T-section as wide as the verandah of each house more strongly reinforces the building in the lateral direction thereof by utilizing the space of verandah.

[0078]

The additional beam formed at both sides of the existing RC-beam connected to earthquake resisting wall, which is made of high strength fluidized concrete or cement mortar and unbonded prestressing steel bars under post-tensioning, provides the ends of reinforced beam with the desirable bending moment, whereby, largely increasing the horizontal strength in the lateral direction perpendicular to the external walls of the building.

[BRIEF DESCRIPTION OF DRAWINGS]

[Fig. 1] A schematic outside view of a part of the building to which RC building seismic reinforcement method utilizing steel portal frames made of wide flange sections without braces is applied.

[Fig. 2] Schematic views of the composition fixing a portal frame made of wide flange sections to the outside of building, (a) shows a sectional view of the example using a welded product of H-shape in cross section and (b) shows a sectional view of the example using a steel column having high bending rigidity.

[Fig. 3] Diagrams of deformation in the horizontal direction of column vs. horizontal load acted thereon, (a) shows load vs. displacement in the case that ordinary steel is used for wide flange section column and (b) shows load vs. displacement in the case that steel of low yield point is used for wide flange section

column.

[Fig. 4] Plan views of existing apartment houses having living spaces partitioned by earthquake resisting walls, (a) shows an example of seismic reinforcement utilizing steel portal frames without braces against the horizontal force in the horizontal direction thereof and (b) shows an example of seismic reinforcement utilizing T-section against the horizontal force in the lateral direction thereof.

[Fig. 5] A plan view of the calculating model according to RC building seismic reinforcement utilizing steel portal frames without braces.

[Fig. 6] A diagram showing load vs. displacement in the horizontal direction of RC-column and wide flange section column having different bending rigidity from that of RC-column.

[Fig. 7] Plan views of combination situating the wide flange section column close to existing RC-structure, (a) shows an example of RC-column covered with the wide flange section column, (b) shows an example of the wide flange section column facing an external surface only of RC-column and (c) shows an example of the chemical anchors fixed to wide flange section column.

[Fig. 8] A elevation view showing the joining part of wide flange section columns vertically in series arranged on a point of contraflexure.

[Fig. 9] A plan view showing a composition fixing T-section to the outer surface of web of the wide flange section column.

[Fig. 10] A elevation view showing a seismic reinforcement composition fixing T-sections to both sides of living space.

[Fig. 11] (a) shows a detailed cross sectional composition of the end of interior RC-beam taking along line A-A in (c), (b) shows a view taking along line B-B in (c) and (c) shows a sectional view of the interior RC-beam supporting floor slab.

[Fig. 12] Cross sections of reinforced column, (a) shows original RC-column, (b) shows RC-column covered with additional reinforced concrete and (c) shows RC-column wound by steel plates.

[Fig. 13] (a) shows a schematic view of steel portal frame buried in the wall and (b) shows a schematic view of steel portal frame fixed to the external surfaces of columns and beams.

[Fig. 14] Schematic views of the deformation of existing RC-structure and steel portal frame fixed thereto under the horizontal load, (a) shows the behavior of RC-

column and RC-beam in RC-structure and (b) shows the behavior of steel column deforming together with existing RC-column.

[Fig. 15] A schematic views of the transmission of stress in RC-structure reinforced by steel portal frames with braces.

[BIEF DESCRIPTION OF SYMBOLS] 1 : RC-structure (RC-frame), 2 : window, 3 : portal frame made of wide flange sections (steel portal frame), 4 : steel column (wide flange section column), 4w, 4W : web, 5 : existing RC-column, 6 : steel beam (wide flange section beam), 7 : external wall, 8 : existing RC-beam, 9 : connecting part, 10 : combination of RC-column and wide flange section column, 22 : tie hoop, 23 : vertical bar, 24 : concrete, 25, 25A : T-section, 25a : leg, 26A : interior RC-beam, 26B : earthquake resisting wall, 27 : verandah, 30 : high strength fluidized concrete and 31 : bunbonded prestressing steel bar